

The Ganymede Laser Altimeter – Instrument design overview with radiation hard transmitter

H. Hussmann¹, C. Althaus^{*1}, K. Lingenauber¹, R. Kallenbach¹, H. Michaelis¹, J. Oberst¹, S. Del Torno¹, G. Steinbrügge¹, K. Enya², M. Kobayashi³ and the GALA team

3rd International Workshop on Instrumentation for Planetary Missions

October 24-27, 2016, Pasadena

¹DLR Institute of Planetary Research

²Japan Aerospace Exploration Agency

³Planetary Exploration Research Center,
Chiba Institute of Technology



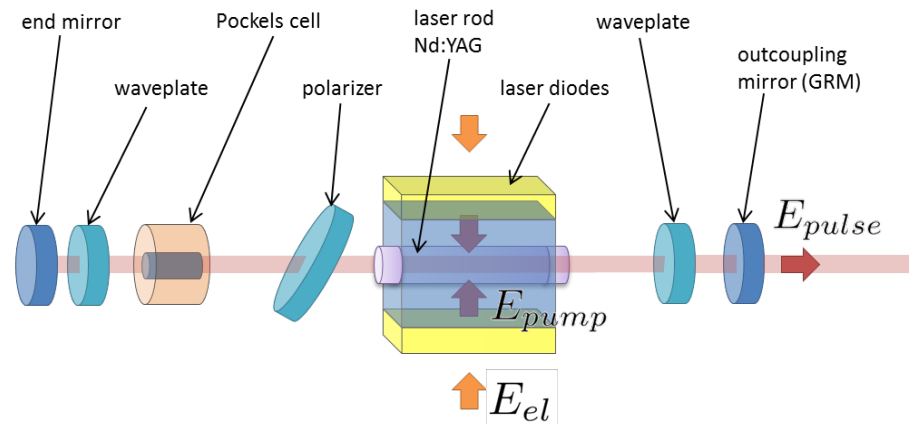
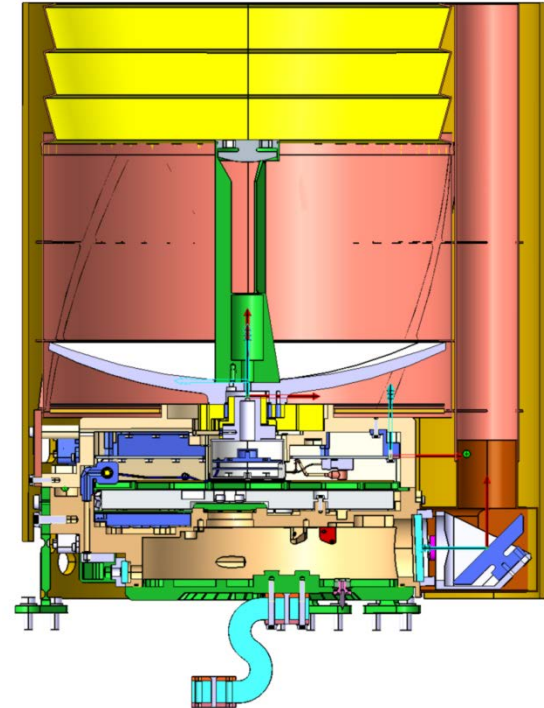
Knowledge for Tomorrow



structure --- JUICE mission --- science goals --- GALA instrument --- receiver module --- transmitter laser --- tools & models --- conclusion

Structure

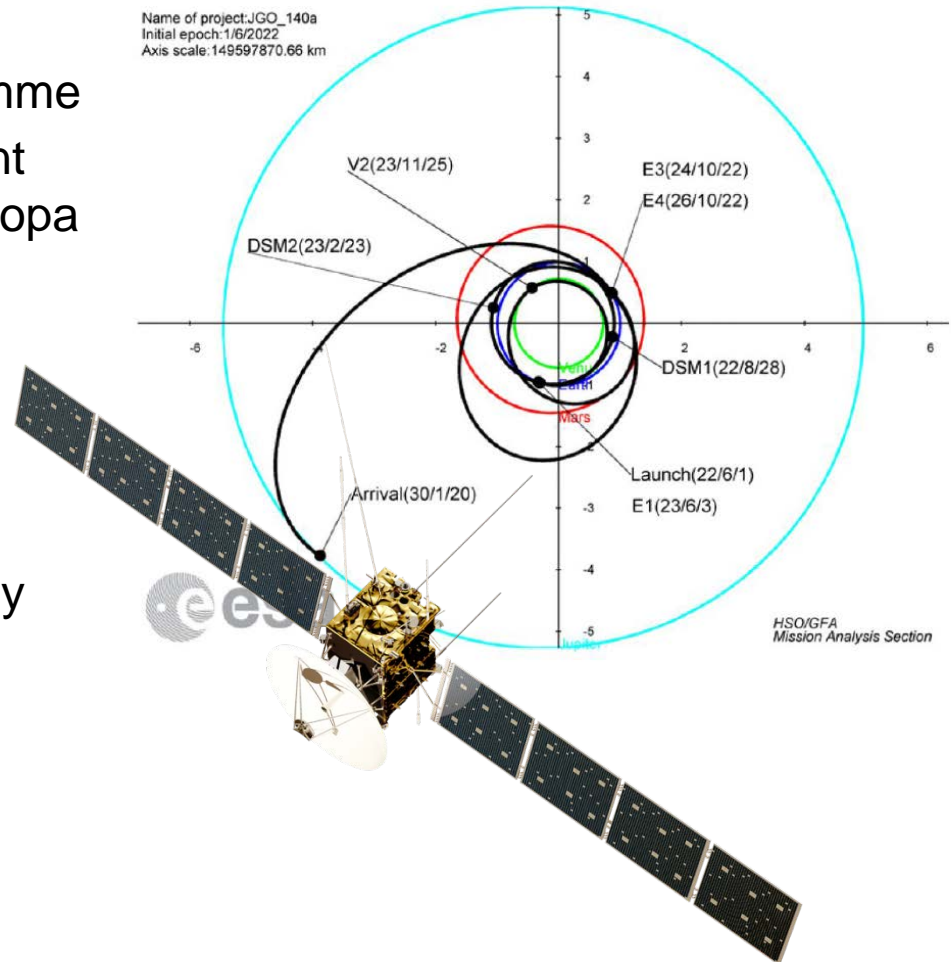
- JUICE mission and environment
- GALA science goals
- GALA instrument overview
- receiver module
- transmitter laser
- tools and models
- conclusion



structure --- **JUICE mission** --- science goals --- GALA instrument --- receiver module --- transmitter laser --- tools & models --- conclusion

JUICE mission

- part of ESA's Cosmic Vision Programme
- to study Jupiter's plasma environment and the 3 icy moons Ganymede, Europa and Callisto
- S/C shall be launched in 2022 on an Ariane 5 rocket
- 8 year cruise phase with fly-bys at Venus, Earth and Mars
- then 3 years the orbit will be gradually adjusted, several fly-bys at Callisto, Europa and Ganymede
- finally 500 km circular orbit around Ganymede for 150 days
- 10 scientific instruments onboard

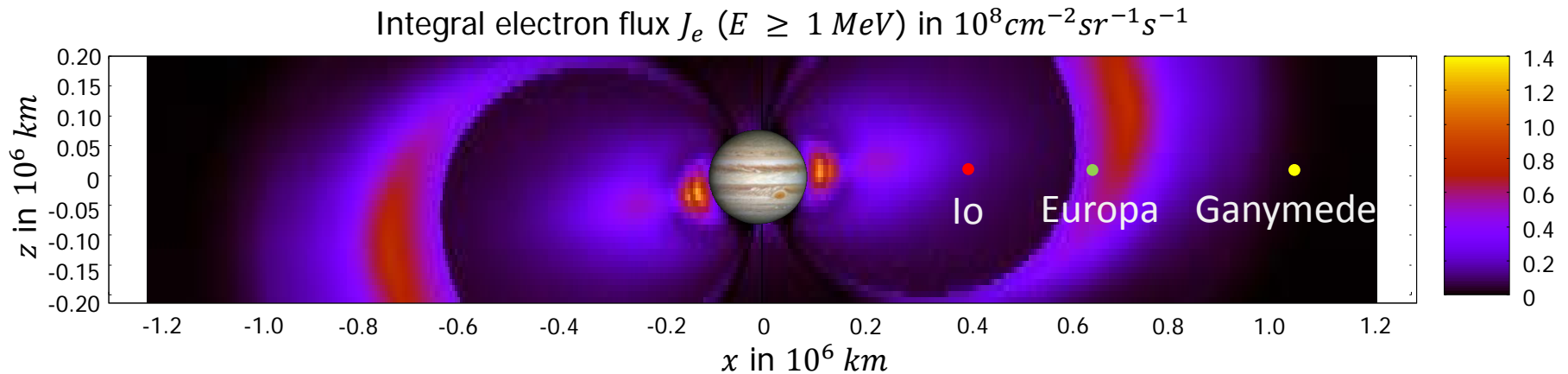


Credit: ESA/SRE(2014)1; JUJupiter ICy moons Explorer; Definition Study Report



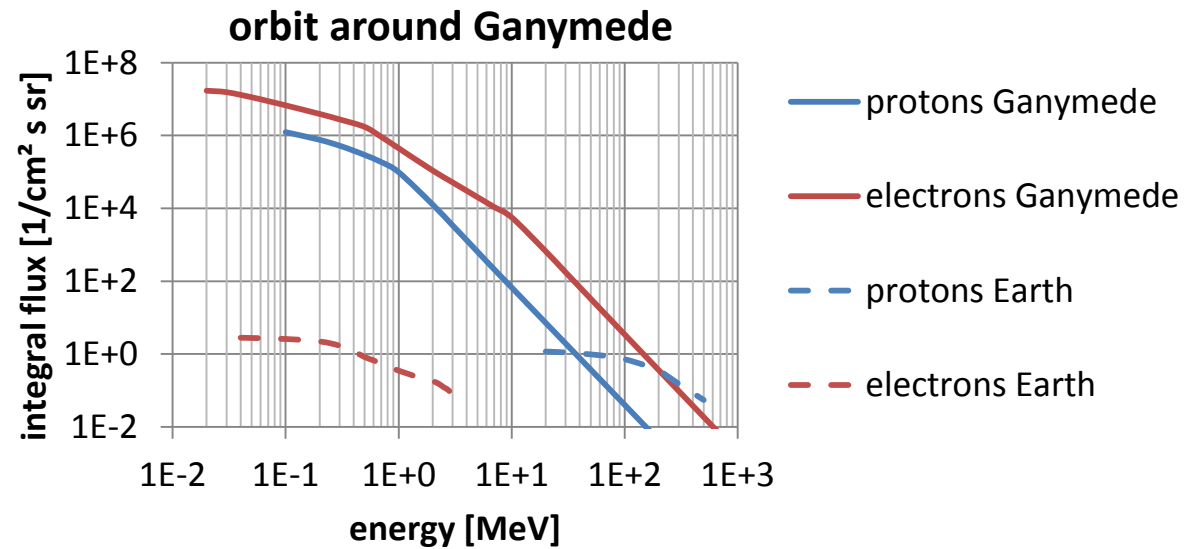
structure --- **JUICE mission** --- science goals --- GALA instrument --- receiver module --- transmitter laser --- tools & models --- conclusion

JUICE environment



Radiation Dose over mission:

- unshielded instrument
TID > 200,000 krad
- spherical shielding of 20 mm Al
TID ~ 60 krad
(cf. simulation values are between 30...60 krad)



GALA science goals

- **Topography**

Global topography up to degree and order 40

Vertical resolution < 5 m

Test for hydrostatic equilibrium by measuring

Regional 10 - 50 km spacing between the tracks

Locally < 10 km spacing between the tracks

- **Measure radial tidal deformations**

Tidal Love number h_2 with an absolute accuracy < 0.03

Constrain the ice shell thickness to ± 20 km.

Goal: Constrain the tidal phase-lag

- **Determine the satellite's dynamical rotational state**

Obliquity

Rotation rate

Longitudinal librations

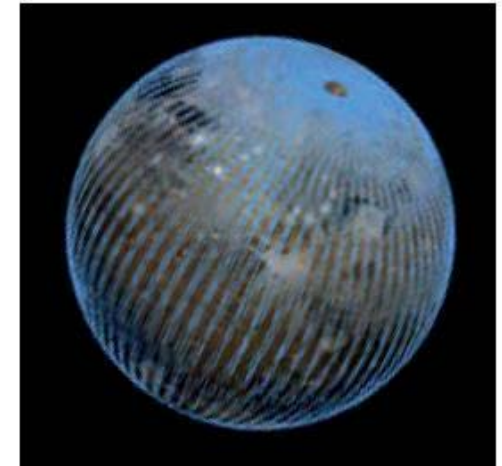
Drift of the rotation axis

- **Regional slopes & roughness**

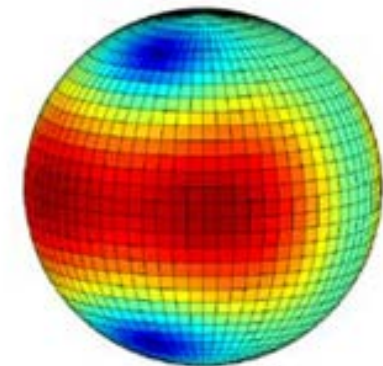
Slope from spot to spot

Roughness inside a laser footprint (~ 30 m)

- **Albedo at the laser wavelength (1064 nm)**



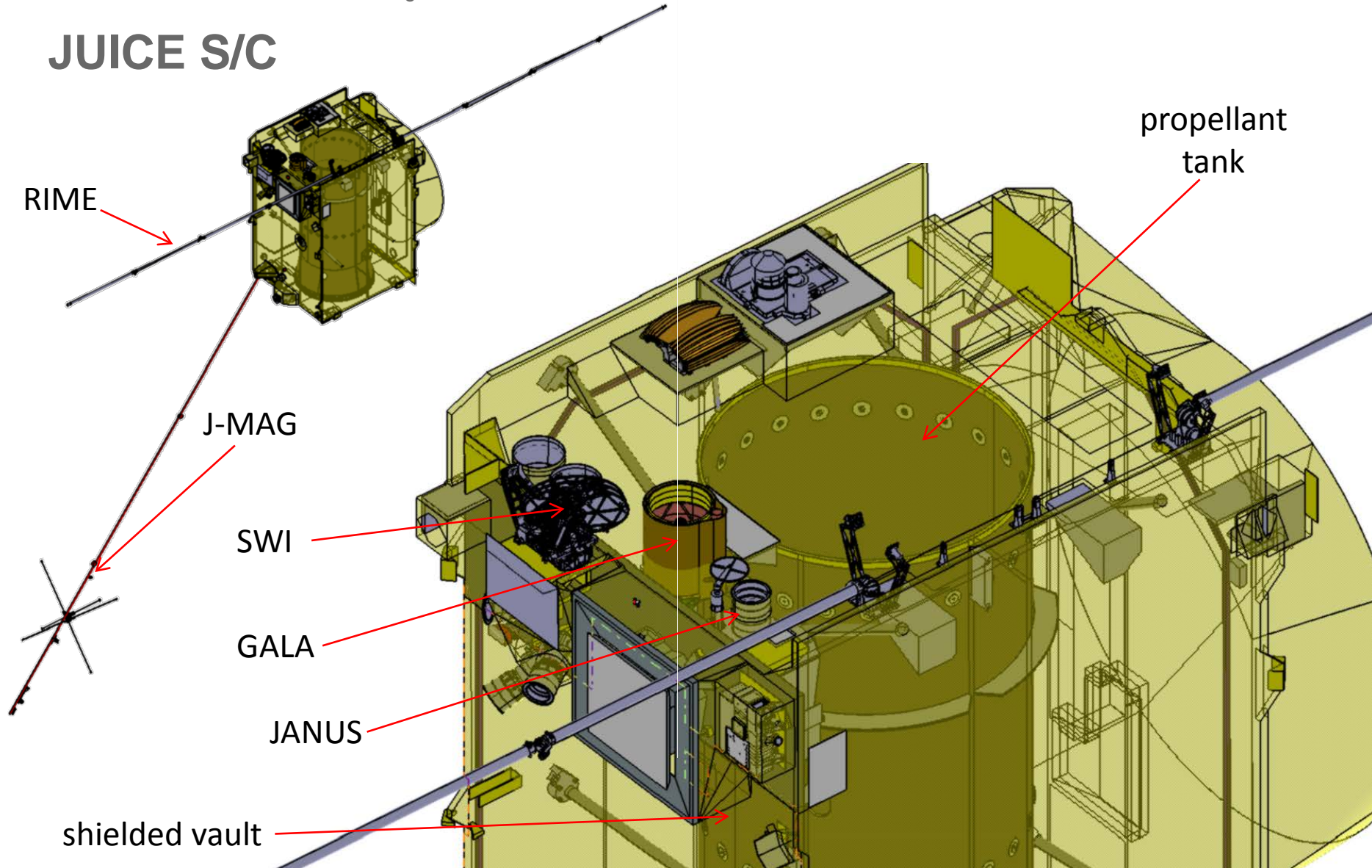
Global coverage for shape and tidal deformation (not all tracks are shown)



Maximal radial tidal deformation

structure --- JUICE mission --- science goals --- **GALA instrument** --- receiver module --- transmitter laser --- tools & models --- conclusion

JUICE S/C



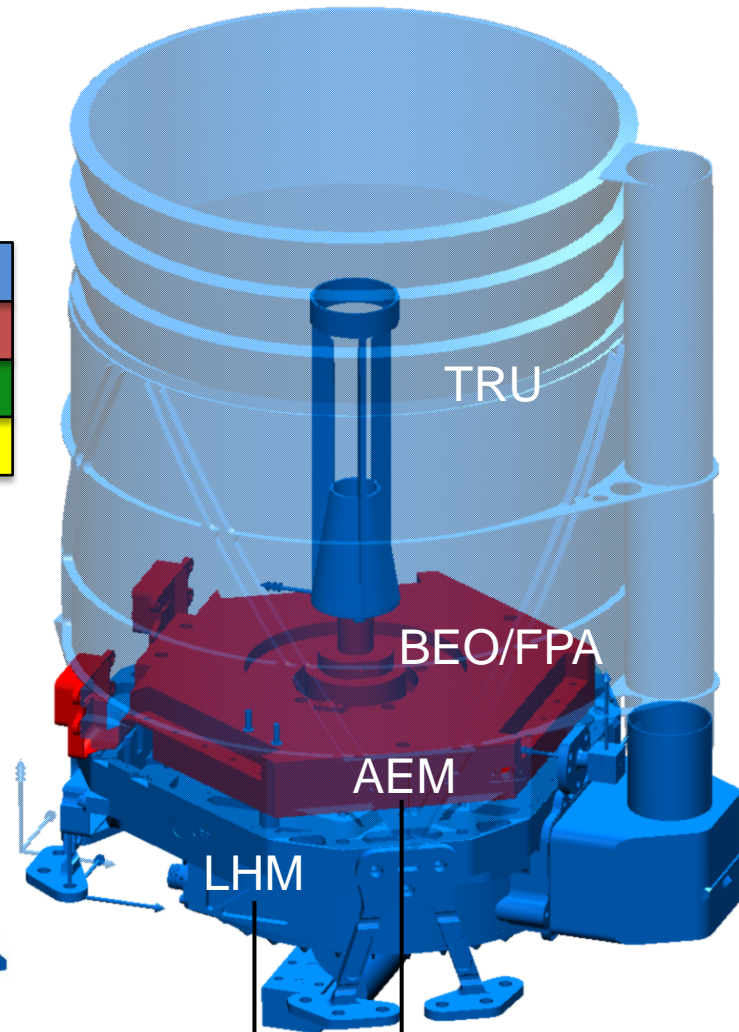
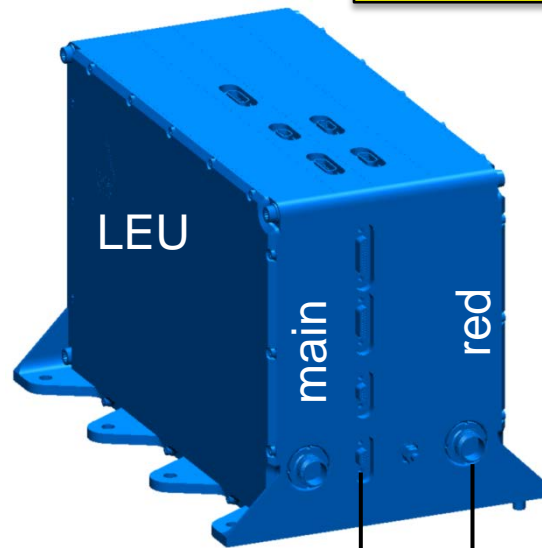
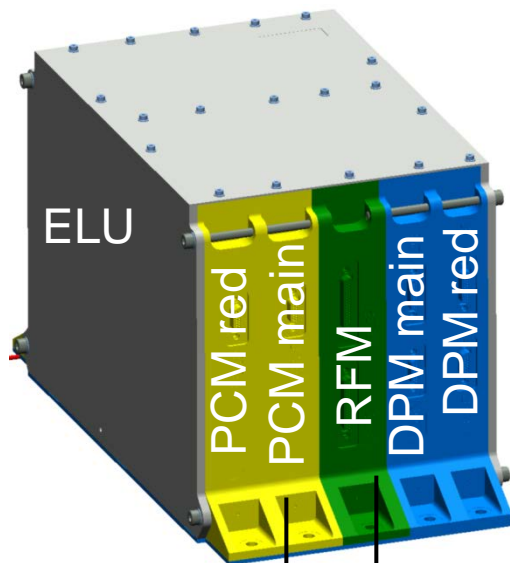
structure --- JUICE mission --- science goals --- **GALA instrument** --- receiver module --- transmitter laser --- tools & models --- conclusion

GALA instrument overview (1)

- international team from Germany (DLR), Japan (JAXA/CIT), Switzerland (UBe) and Spain (IAA)

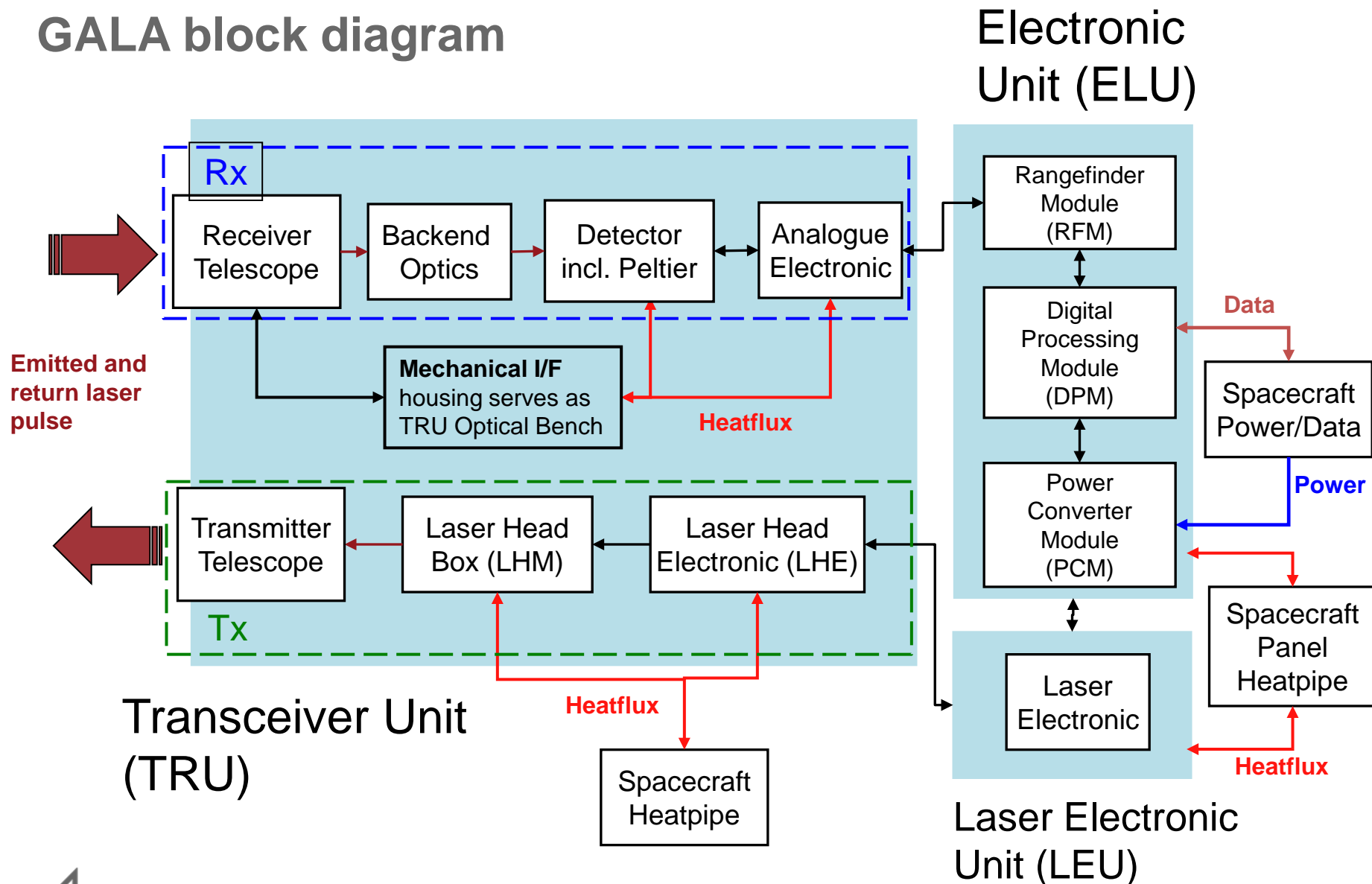


Germany
Japan
Switzerland
Spain



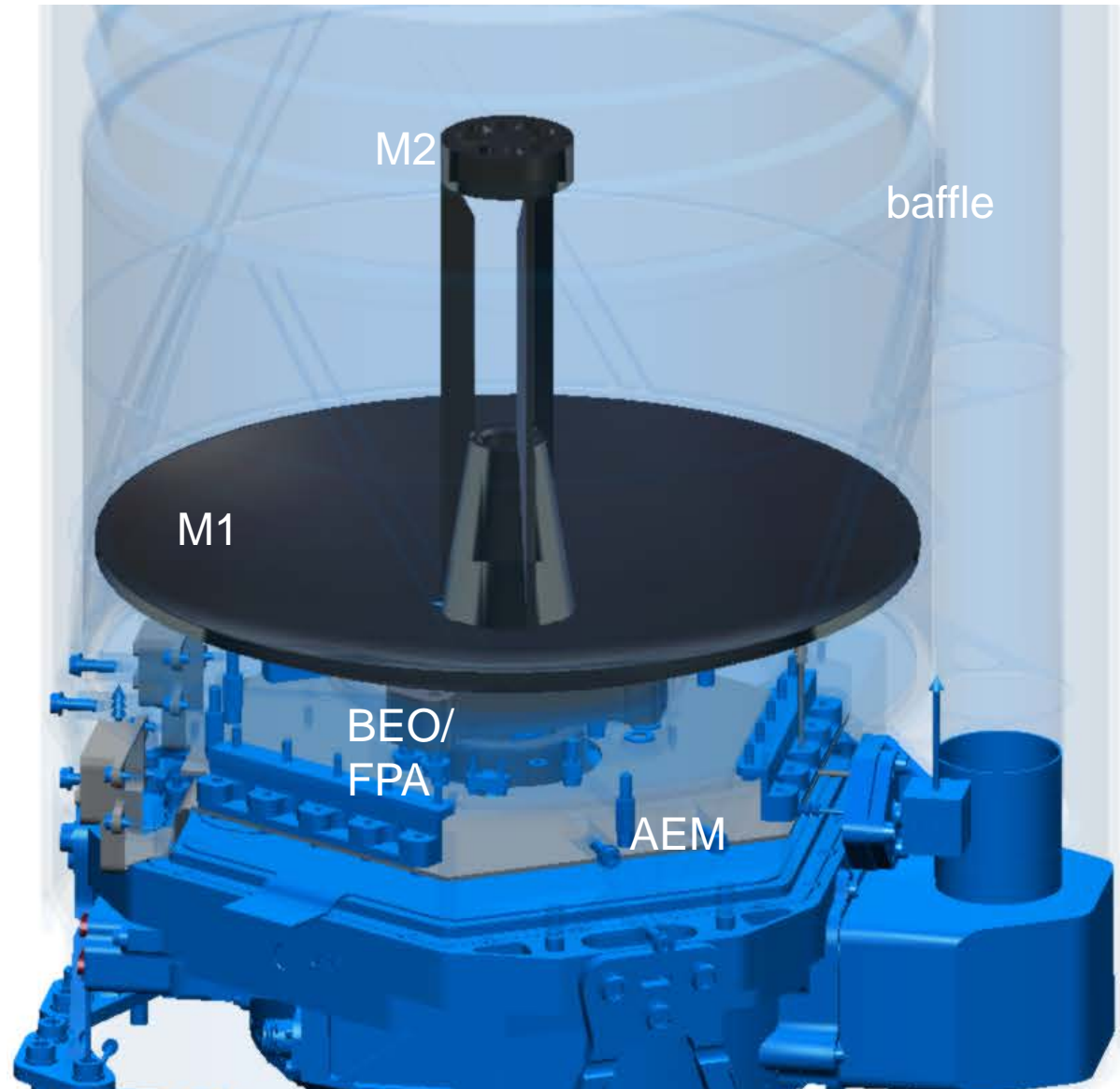
structure --- JUICE mission --- science goals --- **GALA instrument** --- receiver module --- transmitter laser --- tools & models --- conclusion

GALA block diagram



Receiver module

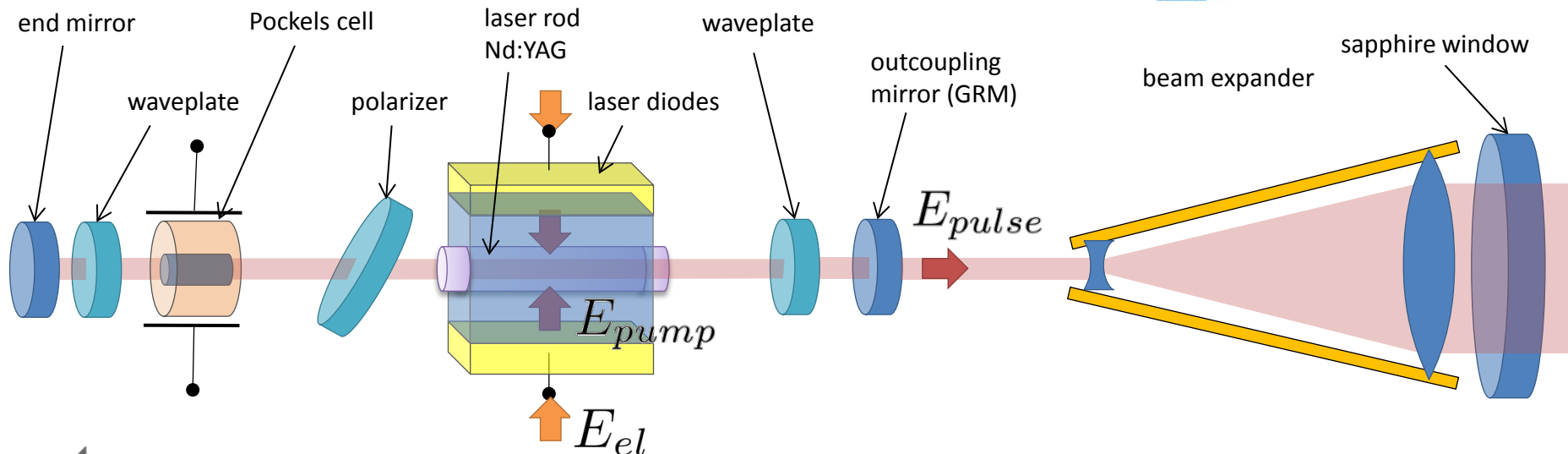
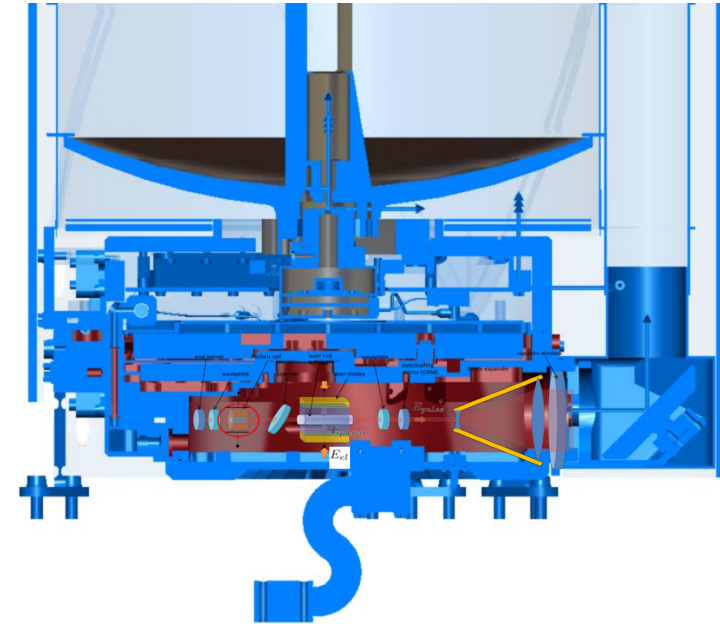
- Ritchey–Chrétien telescope
- 25 cm diameter
- lightweight design
- gold surface coating
- protection by straylight baffle for RX and TX
- backend optics with 1064 narrow bandpass filter and focal plane assembly with APD
- 200 MSamples per sec digital output
- digital filter matching in ELU RFM



structure --- JUICE mission --- science goals --- GALA instrument --- receiver module --- **transmitter laser** --- tools & models --- conclusion

Transmitter laser

- drivers: radiation hardness, efficiency, reliability, pulse properties, volume/mass
- different laser rods tested (up to 2 Mrad)
- optical coatings robustness and LIDT tested
- electric discharge effects of glasses and coatings not observed for 10 nA/cm²
- laser diode performance under radiation in evaluation programme



Laser cavity

- cavity optimization for low threshold and high slope
- Nd:YAG emits at 1064 nm; provides good optical properties; good absorption at 808 nm

$$E = \frac{Ah\nu}{2\sigma\gamma} \ln \frac{1}{R} \ln \frac{n_i}{n_f}$$

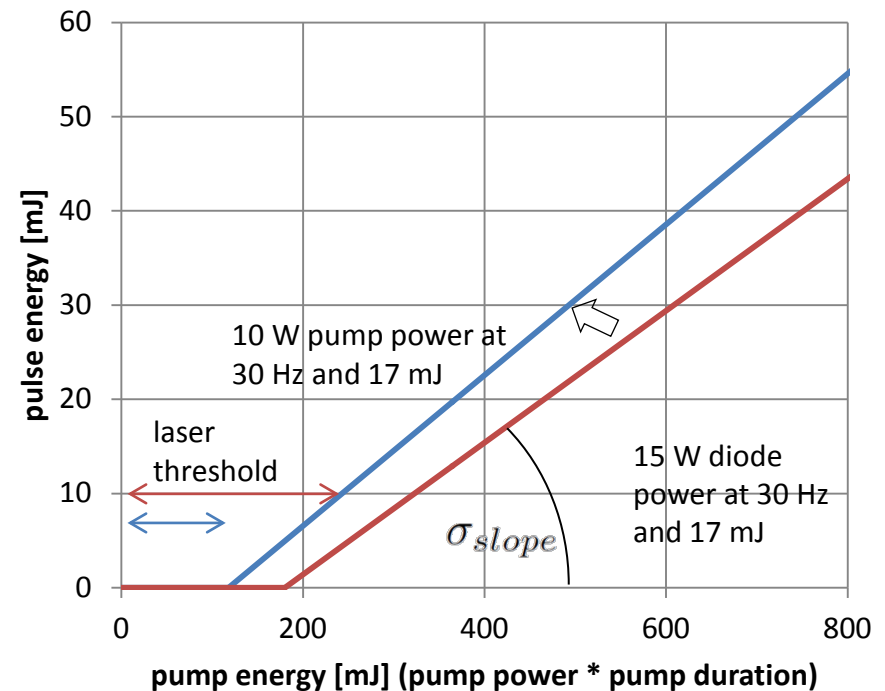
pulse energy (points to E)
 mode area (points to A)
 small signal gain (points to $\ln \frac{n_i}{n_f}$)

$$P_{thr} = \left(\frac{L - \ln R}{2} \right) \frac{Ah\nu}{\eta\sigma\tau_L}$$

$$\sigma_{slope} = \left(\frac{-\ln R}{L - \ln R} \right) \eta$$

pump efficiency, overlap efficiency,
 diode efficiency, quantum efficiency

Laser energy vs. pump energy



Laser rod Nd:YAG w/ and w/o Cr³⁺

- Cr³⁺ co-doping of Nd:YAG is considered as radiation resistant
- effective energy transfer mechanism from Cr³⁺ to Nd³⁺ is known (Kiss and Duncan, 1964)
- color center formation due to iron impurities (Fe→Fe²⁺) during ionizing radiation (UV and gamma) (Glebov, 2010)
- when co-doped with Cr³⁺ ionization creates first further ionization of chromium
- positive effect of Cr³⁺ could not be verified
 - due to high quality of Nd:YAG rods
 - furthermore lifetime reduction of Nd with Cr³⁺ is reported

→selected rod material: Nd:YAG

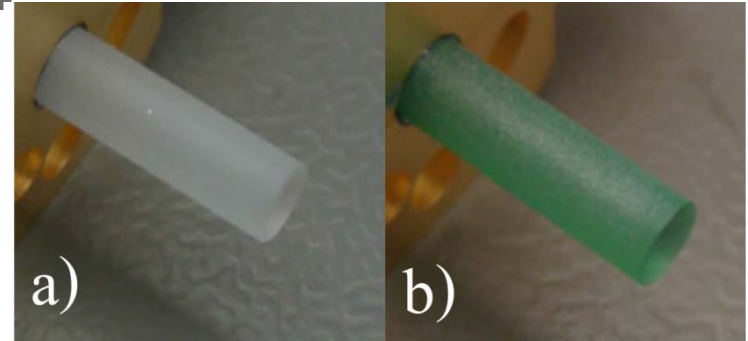
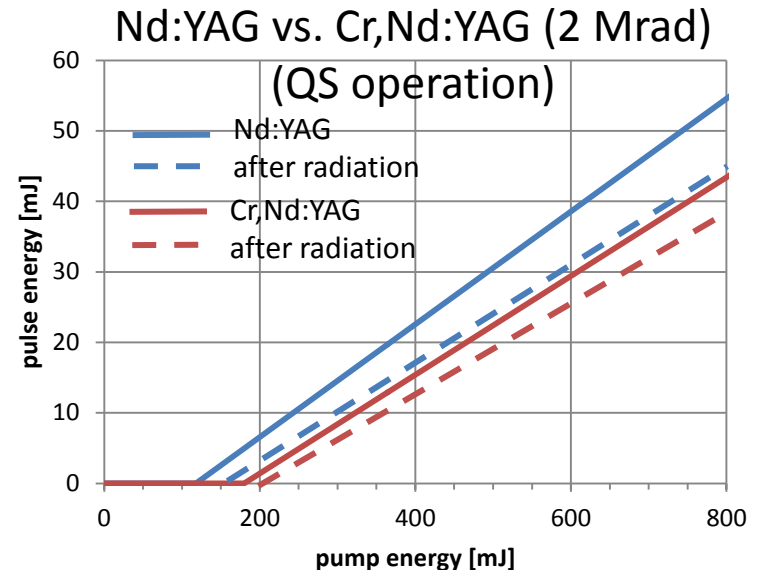


Fig. 5: Nd:YAG laser rod (a) and Cr³⁺,Nd:YAG laser rod. It was figured out that the Nd:YAG performs better in the GALA instrument.



structure --- JUICE mission --- science goals --- GALA instrument --- receiver module --- transmitter laser --- **tools & models** --- conclusion

Tools and models

- laser performance model that reflects the influences of design, environmental and degradation factors
- based on four level laser rate equations and adjusted by experimental data
 - electrical measurements data from breadboard as input
 - optical data after irradiation
 - degradation of electrical performance of opto-electronic devices
- SPENVIS databases provides data about the radiation environment and models for radiation effects and charging
- GRAS and FastRad simulations

SPENVIS

NAVIGATION

- Home
- Access
- Register
- About SPENVIS
- Documentation
- Credits
- Rules of conduct
- My account
- Forums
- Bug tracker
- Lost password



Welcome to **ESA's** Space Environment Information System, a WWW interface to models of the space environment and its effects, including the cosmic rays, natural radiation belts, solar energetic particles, plasmas, gases, and "micro-particles".

Space Situational Awareness
In the framework of ESA's Space Situational Awareness Programme, the version 4.6.4 of SPENVIS has been re-deployed in Redu Data Centre.

Need help?
Beside a large set of contextual help pages, the SPENVIS system includes a forum where users can exchange their experiences and tips. In case of problems, please consult our bug tracker system and feel free to post any bugs.

If you have forgotten your password, you can reset it [here](#). If you want to change your password, you can do it [here](#).

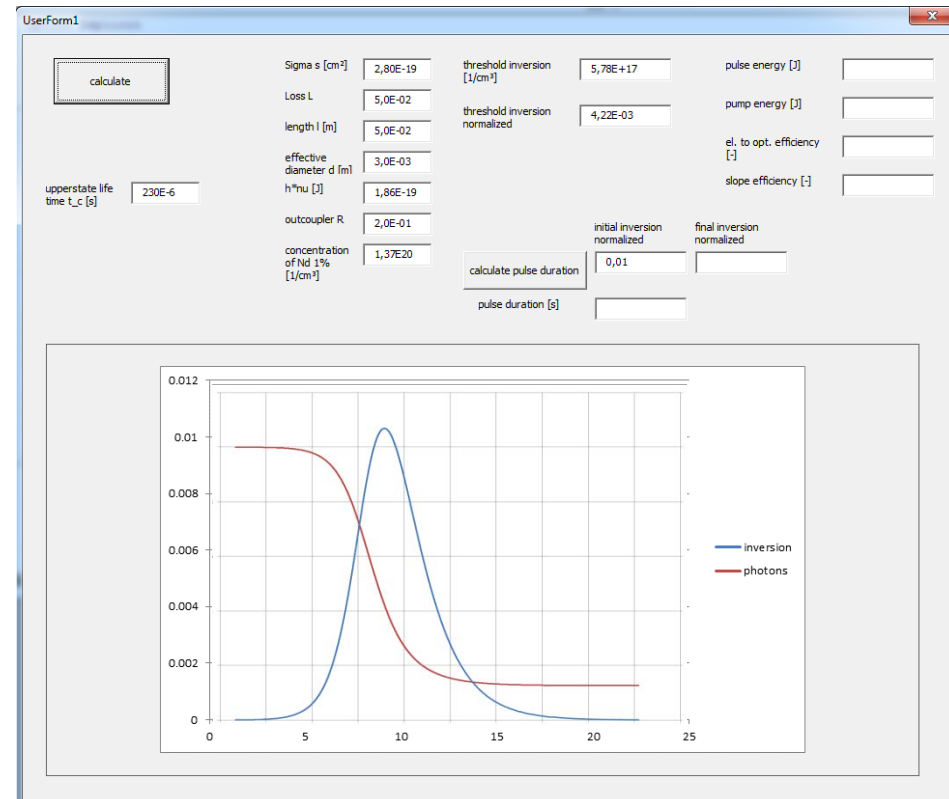
Registration
Use of SPENVIS on this site is **free of charge**, but a user registration is required. Please read the **terms & conditions** before registering.

If you are student or teacher, please read [this](#) first.

[Register now](#)

System requirements
SPENVIS requires a browser with JavaScript support (tested with Firefox 23 and MS-IE 9). Some outputs require a **VRML/X3D plugin** (tested with Octave Player 2.3.0.3).

Current version
The current version of SPENVIS (4.6.7) was **released** on October 4, 2013.



Conclusion

- highly demanding radiation environment and long mission duration
- thick shielding is mandatory → compact and mass efficient TRU design (4 kg shielding in a 12 kg unit)
- extensive testing of components (optical/opto-electronic) done for qualification
 - especially 3 and 15 MeV electrons tests
 - TID and TNID
 - protons play secondary role
 - charging effects likely not critical
 - noise effects on APD
- efficiency of the laser depends strongly on small signal gain and low lasing threshold
 - optimization of laser cavity design
 - 200 A drive current for laser diodes
 - short pockells cell rise time ~10...15 ns
- Nd:YAG rod without Cr^{3+} provides better overall performance
- optical to optical efficiency is ~0.09; electrical to optical ~0.04
- LDA qualification programme running



Thank you
for your attention!

